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PREVENTING AND CONTROLLING WATER-CONDUCTING ROT IN BUILDINGS

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Most decay in buildings is caused by a number of fungi that attack wood previously wetted by rain seepage, leaky plumbing, and condensation. This decay does not extend appreciably beyond the area wetted. Occasionally, however, a water-conducting fungus attacks. These fungi, like other decayers, start at some point where the wood is moist, but if conditions are right they can moisten and advance in wood that would otherwise be too dry to decay. This is the basis for the misnomer "dry rot" for the work of these fungi. Fortunately, the water conductors are of infrequent occurrence. When they do occur, damage may be extensive and necessitate costly replacements.

During the past 25 years, the Division of Forest Pathology has studied more than 35 cases of water-conducting rot in the southern States. The present analysis of these cases shows the main structural features and conditions associated with attack and how control can best be attained. It is hoped that this analysis will allay fears caused by some alarmist publications in the past and also disclose to the building owner less drastic and less costly control measures than have been commonly recommended.

DESCRIPTIONS OF WATER-CONDUCTING FUNGI

There are two important water-conducting fungi: *Merulius lacrymans* Fr. and *Poria incrassata* (B. and C.) Burt. The former is one of the most common building decay fungi in Europe (4).[1/] It is occasionally found in the northern United States, but is of little or no importance in the South.

1/ Underscored numbers in parentheses refer to Literature Cited, p. 14.

Poria incrassata, hereafter referred to as *Poria*, is by far the most destructive water-conducting fungus in the United States. It is most prevalent in the warmer, more humid coastal regions of the South, East, and West but has been found in most of the States. Baxter (1) suggests that its occurrence in the North may be due to the importation of infected lumber from the South or from the West Coast. Even in the southern and West Coast regions *Poria* is not common.

Poria has been found mainly in buildings. This may mean that in buildings the fungus finds the protected locations best suited to its development. Since its fruiting structure is fragile and would soon disappear under most outdoor conditions, the fungus might be noticed less than would species with durable fruiting bodies. Hence the restriction in occurrence may be more apparent than real. The fruiting body, vegetative mycelium, rhizomorphs, and cultures have been described (5, 6).

When a water conductor occurs in a building, the extent and rapidity of attack may be spectacular (6, 9). *Poria* causes a brown cubical rot, usually starting in the substructure--the sills, first-floor joists, nailing strips, wall plates, etc. (fig. 1). Later it may work up into the walls and even attack the second floor. By this time all structural and trim items in the area of the original attack may be damaged. Oftentimes owners are unaware of the attack until a floor fails, doors settle, sunken areas appear in baseboards, or a yellowish-white fungus felt appears under a rug or in a cupboard. When the wall or floor is opened for repairs, extensive yellowish-white mycelial mats (fig. 2) are usually found between sheathing and building paper or between two wood surfaces as finish and subfloors.

Figure 1. --Flooring badly decayed by *Poria*.

Figure 2.--Mycelial growth of Poria on the back of a wood panel.

When extensive damage occurs, rhizomorphs (water-conducting strands) from a small fraction of an inch to 2 inches in diameter can usually be found (fig. 3). They extend from the soil or other constant water source up into the wood structure. It is these rhizomorphs and well-developed mycelial fans that permit Poria to conduct water to wood normally too dry to decay. When decay is more restricted, definite rhizomorphs may be lacking but the mycelial mats show a tendency to form strands. Laboratory studies[2] have shown that Poria can conduct water at least 5 feet up wood columns. Observations in buildings indicate that this fungus can conduct water at least 20 feet horizontally and 12 feet vertically.

2/ Scheffer, T. C. Importance of conducted water and "auto-humidification" in decay by the "dry-rot" fungus Poria incrassata. U. S. Dept. Agr. Div. Forest Path. Unpublished report. Nov. 1941.

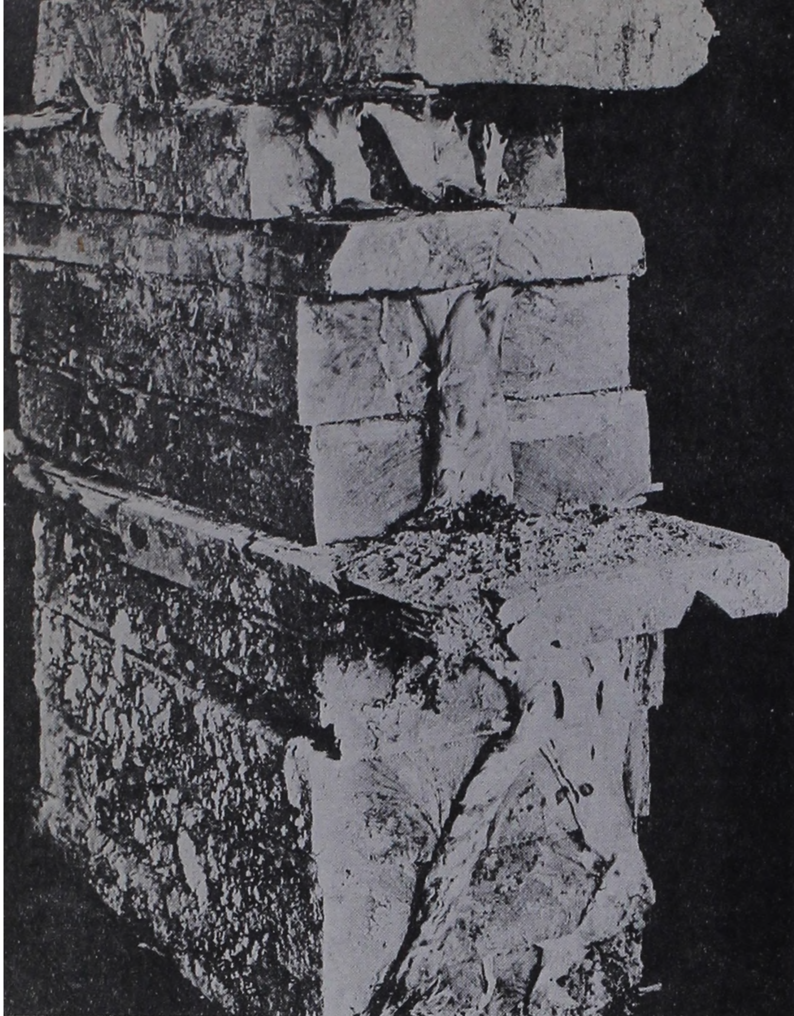

Figure 3. --Water-conducting rhizomorphs growing on the ends of piled lumber.

All fungi liberate water as one of the end products of wood decay. The brown rotters, which include the water conductors, are particularly proficient in this respect (4). This "autohumidification" undoubtedly aids in the development of water-conducting fungi. However, there seems to be no basis for the fear that Poria, when once well established in a building, can exist with no other source of water than autohumidification. Studies by Scheffer 2/ suggest that the critical relative humidity for the progress of Poria in freely exposed wood not exceeding 2 inches in thickness, and with the fungus isolated from sources of water other than autohumidification, would be somewhat above 95 percent. He points out that such humidity would have to be continuous, a condition seldom encountered in buildings. Thus it appears that, under most conditions in buildings, the fungus must depend on conducted water for continued development. There may be some exceptions to this generalization.

Two other physiological factors in the growth of Poria are important in its occurrence and control. Among wood rotters, it is one of the most sensitive to drying (11). In wood with about 8 percent moisture it died in 24 hours; in wood with 13 to 21 percent moisture it died in 12 days or less. This is in contrast to other common building decay fungi like Lenzites saepiaria, which survive several years in air-dry wood (10). The other important factor is Poria's ability to decay heartwood of durable species. Both laboratory studies (5) and field observations show that Poria will seriously attack the heartwood of baldcypress, western redcedar, and redwood as well as less durable common building woods such as pine and Douglas-fir. In contrast, it shows no unusual resistance to such common wood preservatives as creosote, zinc chloride, or pentachlorophenol (2, 7). It does, however, show some resistance to copper fungicides (7).

SURVEY OF <u>PORIA</u> CASES IN THE SOUTH

Since 1928, observations have been made[3/] on cases of water-conducting rot as they were found or reported. Notes were taken on structural features and other factors that might explain why the attack occurred. In many cases, the buildings were watched for several years after control recommendations had been carried out and repairs had been made. The cases in buildings in the South are summarized in table 1.

Sometimes complete information was lacking, but it appears that most attacks occur in relatively new houses or in older houses in which recent structural changes have been made. The most logical interpretation is that *Poria* often is introduced into a building in infected lumber. One known exception to this is the Dothan, Alabama, case (table 1). Even though structural changes had been made 2 years before decay was noticed, they were not involved in the decay. Instead, the decay was centered on an old outside wall against which coal had been piled. Because *Poria* mycelial mats have been observed on coal in other cases, it is assumed that the fungus was introduced into the Dothan house on coal from an infected lumber yard.

All the evidence points to little dissemination of this fungus by air movement of spores. Were this not true, it would be more prevalent in houses with features known to favor attack but which have stood for years without attack. The available information points to a need for better protection of lumber and building supplies in lumber storage sheds as an important factor in prevention. The buyer is fairly sure of getting lumber free of live *Poria* if he insists on the lumber being dry, i.e. below 20 percent moisture content (and preferably below 18 percent) for framing and sheathing, and below 12 percent for all siding and trim (11).

Source of water supporting decay

The worst decay observed was associated with sites with continuously wet soil at some place around the foundation. The wet soil was due to poor drainage, leaky plumbing, lack of provision for carrying roof runoff away from the foundation, continual watering of flower beds, or poorly designed concrete porches that allow excessive seepage into the dirt fill under the slab. In general, the more water present the more

3/ Some of the observations were made by C. Hartley, R. M. Lindgren, T. C. Scheffer, and C. A. Richards.

Table 1. --Summary of factors associated with water-conducting rot in buildings in the South

Location	Type of building	Dates: Constructed	Dates: Altered 2/	Dates: Decay first noticed	Dates: Inspected	Causes contributing to decay 1/ — Source of water: Wet soil	Leaky plumbing	Rain leaks	Green lumber	Leaky downspouts	Wood-soil contacts: Joists or sills	Dirt-filled porches	Foundation forms	Siding, trim, sheathing	Lattice work	Wood foundation	Wood on groundline concrete slab	Inadequate ventilation	Miscellaneous
ALABAMA																			
Dothan 3/	House	1920	1944	1946	1948	P	P	...	...	...	...	...	...	...	...	...	...	...	Decay centered where coal was piled against siding.
Mobile	House	1880?	Yes	...	1940	...	...	P	...	...	...	P*	...	...	P	...	...	...	Dirt-filled porch added at unknown date.
Selma 3/	House	1858	1930	1937	1940	P	...	...	...	P	...	...	P*	...	P	...	...	...	Concrete porch added in 1930. Soil dry except at porch.
FLORIDA																			
Jacksonville	House	1926	No	...	1931	...	...	...	...	...	...	P*	...	...	...	...	...	...	
Lake Wales	House	1920?	Yes	...	1931	...	...	...	...	...	...	...	...	...	...	...	P*	P*	Decay in unventilated wooden locker added to basement.
Lake Wales	House	1920?	No	...	1931	...	...	...	...	...	...	P*	...	...	...	...	P*	P	Partition wall plate on wet concrete basement floor.
Orlando	House	1925?	No	...	1931	...	...	...	...	...	...	...	...	...	...	...	P*	...	
Penny Farms	Houses	1927?	No	...	1930	...	...	...	...	...	...	...	...	...	...	...	P*	...	Several houses involved.
Pensacola	House	1927	No	1930	1931	...	...	...	...	...	...	...	...	...	...	P*	...	...	
Port St. Joe 3/	5 houses	1935?	No	...	1946	P	...	...	...	...	...	...	...	...	...	P*	...	...	Repaired several times.
Tampa	House	1928?	No	...	1931	...	...	P	...	...	...	P*	...	...	...	...	...	...	
Tampa	House	1928?	No	1931	1931	...	...	...	...	...	P*	...	...	...	...	...	...	...	
GEORGIA																			
Bainbridge 3/	House	1931?	No	1941	1941	...	...	...	...	...	...	P*	...	...	...	...	...	...	Rain probably seeped into dirt fill.
LOUISIANA																			
Baton Rouge	House	...	...	...	1940	P	P	...	...	...	P*	P*	...	P*	...	...	...	...	
New Orleans 3/	House	1880?	Yes	...	1942	P	...	...	...	...	P*	...	...	...	P	...	...	...	Joist on pile of mortar left from removing chimney.
New Orleans	House	1850?	Yes	...	1941	P	...	...	...	...	..	...	...	...	...	...	P*	...	Untreated sleepers in groundline concrete slab.
New Orleans 3/	House	1900?	Yes	...	1937	P	...	...	...	...	P*	...	...	...	...	...	P*	...	Sill to new basement room laid on soil.
New Orleans 3/	House	1927?	...	...	1937	...	...	...	...	...	...	P*	...	...	...	...	...	...	
Southport 3/	House	...	Yes	1940	1941	P	...	...	...	...	P*	...	...	P*	...	...	...	...	Rich, wet, flowerbed soil against siding. Untreated nailing strips on soil in basement.
MISSISSIPPI																			
Gulfport 3/	House	1926	No	...	1944	P	...	...	...	...	...	...	...	P*	...	...	...	...	Wood sheathing to ground between stucco and brick piers.
Meridian 3/	House	1890?	Yes	...	1940	P	P	P	...	...	...	P*	...	...	...	...	...	...	Dirt-filled porches added at unknown date.
S. CAROLINA																			
Marion 3/	House	1893	1947	1950	1951	P	...	...	...	P*	...	...	...	...	...	...	...	...	Termite-damage repairs in 1947. Suspect use of infected wood.
TEXAS																			
Denison	House	1910?	1949	1950	1951	P	...	...	P	...	P*	...	...	P	P	P	...	...	Decay in new sapwood addition made in 1949.
Terrell 3/	House	...	...	1939	1940	...	...	...	...	...	...	P	...	P*	...	...	P*	...	Wood skirting touching soil.
LOUISIANA																			
New Orleans	Store	...	...	...	1940	P	...	...	...	...	P*	...	...	...	...	...	...	...	
New Orleans 3/	Duplex	...	Yes	1931?	1931	P	...	...	...	...	...	...	P*	...	...	...	...	...	
MISSISSIPPI																			
Gulfport	Motel	1935?	No	1938	1940	...	P	...	...	...	...	...	...	...	...	...	P*	...	
Hattiesburg	School	1926	No	1929	1929	P	...	...	...	...	...	...	...	...	...	...	...	P	Wood debris piled up to joists.
N. CAROLINA																			
Cherry Point 3/	Apt.	1944	No	1946	1948	P	...	...	P*	...	...	...	...	...	...	...	...	P*	Excessive floor washing.
FLORIDA to LOUISIANA	7 lumber sheds	...	...	...	...	P	...	P	...	...	...	...	...	...	...	P*	...	...	Decay often worked up into stored lumber.

1/ "P" indicates factor present; asterisks indicate main causes. 2/ "Yes" indicates that alterations or changes that added new wood to the house were made at an unknown date.
3/ Successfully treated by measures recommended in this paper.

extensive the damage. In some cases there was a possibility that the main source of water was not the soil but water in wood wetted directly by rain seepage or leaky plumbing. It is assumed that after the fungus is established in such wood, it can progress without ground contacts as long as the leaks remain.

A less common source of water appeared to be operative in the case of the apartment building at Cherry Point, North Carolina. There were no contacts with the soil or moist concrete, and no condensation was evident. Apparently the fungus gained entrance in infected green framing lumber. Because of the tight foundation closure, the water in the green lumber plus metabolic water from the decay may have dried so slowly that decay to the point of wood failure occurred without other additions to the water in the wood. Replacements with dry wood remained sound.

In the South no cases have so far been found in which condensation was an important source of water that supported decay. Such instances have been found in the Washington, D. C., area and--provided ground connections are also broken--are controllable by the use of soil covers (3).

Lack of substructure ventilation may increase the severity of attack but is not a prerequisite of heavy damage. Some of the severest cases observed were in houses on open brick piers. There are usually protected places, such as wall interiors, or the contact areas of flooring with joists or between floor layers, in which the high humidities needed for fungus development are maintained during active decay. Ventilation is probably most important in the borderline cases in which water is derived mainly from green lumber or from condensation.

Structural details associated with Poria attacks

With the exception of the Cherry Point and Dothan cases, all attacks appeared to start at contacts of untreated wood and moist soil or groundline concrete slabs. These contacts, in the order of prevalence, are discussed below.

(1) Dirt-filled porches with an untreated sill or header in contact with the dirt fill or separated from it only by asphalt-impregnated sheathing paper (fig. 4A). The dirt-filled porch has led to so much decay and termite trouble that extreme caution should be exercised in including this type of construction in a building. It is much safer to use a self-supporting slab with the subslab area open to the crawl

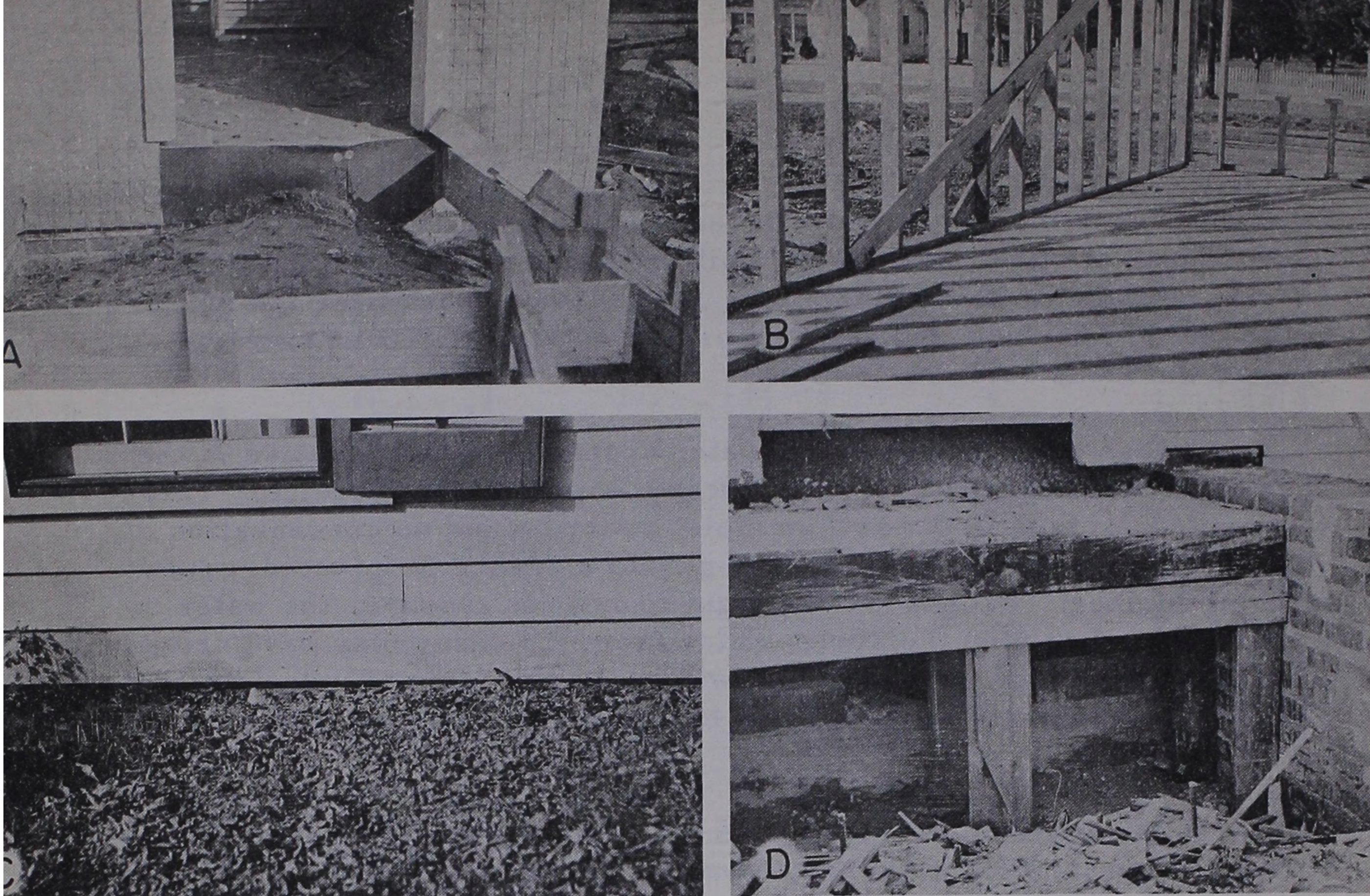

Figure 4. --Some common practices leading to attack by water-conducting fungi. A, The dirt fill for this porch is separated from the untreated sill only by sheathing paper. B, Non-waterproofed groundline concrete slab. C, Untreated wood in contact with soil. D, If these forms are left after the stoop slab is poured, they will make a wooden contact between the soil and the sill of the house.

space or cellar. When the slab is a step or two lower than the house floor the fill may be entirely below the wood, in which case there is little danger. Attack may also be prevented by the insertion of a continuous non-corrosive metal shield. Such a shield should extend down from under the siding, over the outside and underside of the sill to the crawl space, and there should bend downward at 45^{o} for 2 inches. There is also a possibility that attack of both decay and termites can be prevented by treating the fill with fungicides and insecticides before the slab is poured. Tests on the effectiveness of soil fungicides have been started. The easiest way, however, is to avoid the dirt fill.

When attack involves a dirt fill the usual correction consists of removing a section of the foundation and excavating the fill away from the sill. The excavation should be sufficient to permit crawling along the sill for inspection. The concrete slab and foundation exposed by the excavation should be scraped clean and painted or sprayed with

creosote or with 5 percent pentachlorophenol in a petroleum oil. In one case a 12-inch strip of the porch slab was removed next to the sill and enough fill removed to insert a new pressure-treated sill. The excavation was filled with creosote-treated cinders and the slab was repaired. This, however, did not leave as finished-appearing a job as the usual excavation from the underside.

(2) Joists or sills touching the soil. This group included cases in which sills or joists touched piles of earth thrown up in laying plumbing lines or digging furnace pits; non-leveling of natural ground humps; sills or nailing strips of untreated wood laid directly on the soil, particularly in basements or unexcavated store floors; and a pile of mortar left during removal of a fireplace. Indirect contacts included were a pile of cut-off lumber ends left under the building and touching a joist, and contacts of joists and stumps left under the house.

Many of these cases never would have occurred had a little care been exercised during construction. Where it is necessary to have a floor on the ground, a concrete slab is best (but see point 3 below for precautions about wood coverings). If wood of any kind must be placed directly on the ground it should be treated with such suitable preservatives as creosote or pentachlorophenol, with solution retentions of at least 6 pounds per cubic foot.

(3) Untreated wood on moist groundline concrete slabs (fig. 4B). Even when water-conducting rot does not occur, this condition usually leads to floor buckling and damp living quarters. Poria can become established in wall plates and nailing strips and can secure enough water from the soil through the slab to cause extensive decay. When severe water-conducting rot is associated with wooden floors and walls on a damp concrete slab, there is no sure way of control except to remove the floor, replace the wall plates with pressure-treated wood, and add a moisture-proof membrane to the slab, being sure that it extends under the wall plates. New nailing strips and subflooring should be pressure-treated. This is the most expensive and discouraging type of Poria attack to correct. Many of the houses attacked in this way have been torn down completely and replaced with other types of construction. When the attack is not too severe there is a possibility that control could be secured by removing wooden floors and replacing badly damaged wood in the walls, using treated plates. Then the unattacked plates could be given some protection by flowing 5 percent pentachlorophenol over and under them. A non-wood floor would then be used. There is no record of such a treatment but it should stand a good chance of success.

Because of the difficulty and expense of correcting an attack in wooden houses laid on groundline slabs, care should be taken to insure that the construction is safe from the start. Concrete slabs for houses should be elevated so the top surface is 12 inches above grade, the slab poured on a layer of gravel, and a water-proof membrane used either below or on top of the slab. No grade stakes should be left in the slab. When these recommendations are followed, there usually is no trouble with decay. Nevertheless it is best also to use treated wall plates, nailing strips, and subflooring.

As a substitute for treated wall plates, the current tendency is to place wall plates on sheet metal flashing bent up over the sides of the plates. Sometimes asphalt roofing is used as flashing. Such metal or roofing flashing should not be used as a substitute for a complete water-proof membrane when slabs are to be covered with wood flooring.

An analogous condition exists in damp basements. It is best to use only treated wood or non-wood materials in contact with basement floors.

(4) Sheathing, siding, and trim in contact with the soil (fig. 4C). In most cases this was due to careless grading or the building up of flower beds. Rich, mulched flower beds seem to be an ideal place for the rooting of a well-developed rhizomorph system. As long as siding and trim is kept to the usually recommended minimum of 6 inches from the soil, there should be no danger of its being an entrance point for *Poria*. A number of houses were found, including one with heavy *Poria* attack, in which the sheathing was brought down to the soil to act as a support for metal lath and stucco. The wood between the stucco and the foundation piers could be removed only by removing the stucco.

(5) Wooden foundation. The house in Denison, Texas, was on Osage-orange foundation piers. These apparently were unattacked and were not replaced during repairs. However, in several other houses the fungus entered through cypress and pine foundation piers. Replacement with concrete or brick piers stopped further attack. In many lumber storage sheds, cypress or heart pine foundations have been used for lumber piles. This has led to frequent attack in stored lumber. The use of concrete footings extending 6 to 12 inches above grade has stopped the trouble.

(6) Wooden forms left on foundations, steps, and porch slabs (fig. 4D). Although only two cases were traceable to this condition, the common practice of leaving forms in hidden places is risky. The cost of

removal is so small that it is almost inconceivable that people leave them. If decay does not occur, termite attack may.

PREVENTION OF ATTACK

Although no random sampling of houses has been made, it is obvious from general observations that many of the features mentioned above commonly occur without Poria attack. The logical explanation is that Poria is of limited occurrence and is distributed mainly in infected building material. For example, although it is a common practice to leave forms under concrete porch slabs or back of concrete steps, only 2 cases of attack at this point were found.

This raises a real problem in control, i. e., one of convincing people that a given construction feature can be dangerous even though it does not always lead to trouble. The added cost of avoiding dangerous features during original construction or even (in many cases) of removing the danger after construction is small. Hundreds of dollars for repairs can often be saved by a few hours of extra labor during or after construction.

The main precautions for preventing attack in new construction are:

1. Use only uninfected lumber below 20 percent moisture content, i. e., fully air-dried or kiln-dried.

2. Be sure the construction plan calls for no untreated wood in contact with the soil. Framing generally should be 18 inches above grade and trim at least 6 inches. If wooden steps, lattice between foundation piers, or any other wood is likely to be on or near the ground, it should be adequately treated with a preservative.

3. Be sure that changes in grading do not create wood-soil contacts.

4. Remove all forms used in pouring concrete. Also remove wood debris from the crawl space.

5. Provide adequate drainage to prevent water accumulations near or under the house.

6. Do not build enclosed partitions, boxed steps, bins, or rooms in a damp basement unless treated wood or non-wood materials are used.

7. Beware of dirt-filled porches. See the previous section on cases associated with this.

8. If a groundline concrete slab is used, be sure it is moisture-proof. See the previous section on cases associated with this.

9. If condensation occurs under a basementless house, use a soil cover (3).

In summary, prevention of water-conducting rot is essentially the use of dry sound lumber in construction and the use of designs that keep untreated wood away from the soil or damp concrete or masonry.

WHAT TO DO WHEN PORIA ROT IS FOUND

The common recommendations for stopping an attack by Poria have been drastic (6, 8, 9, 12). They usually call for removing all decayed wood and all apparently sound wood within 2 or 3 feet of visible decay, as well as the correction of structural faults. The requirement for the removal of apparently sound wood within 2 or 3 feet of visible infection turns the correction of even a minor attack into a major and costly operation.

The laboratory studies showing the sensitivity of Poria to drying and observations in attacked buildings show that this drastic control is unnecessary. The evidence is that not only the adjacent sound wood but any infected wood with sufficient strength can be left if the source of outside water is removed. If the attack has been severe, replacements of weak wood will be costly, but if the attack is discovered early, sometimes no replacements are necessary. The most difficult corrections occur with houses on groundline concrete slabs (for control measures, see point 3, page 9).

Correction always starts with a search for the source of water and its removal. This means breaking all the contacts between the soil and the wood of the building. Foundations in the decayed part of the building must be inspected for rhizomorphs that connect the wood with the soil or moist concrete. Any rootlike structures should be scraped from the foundation. In brick, concrete block, and stone work, rhizomorphs may penetrate voids or loose mortar and be invisible from

the outside. If the mortar is crumbly, it is safest either to remove a few top courses of brick and replace them with fresh mortar or to insert a continuous metal termite shield between the foundation and the sill. Foundation surfaces over which rhizomorphs have spread should be brushed with a clear preservative like 5 percent pentachlorophenol in a light petroleum solvent--or, if staining and odor are not objectionable, creosote will do. Other factors in moisture control may involve repair of leaks in plumbing, roofs, siding, or downspouts; provisions for better surface drainage; or the addition of a soil cover (3) if condensation occurs under a basementless house.

After these sources of water are removed, decayed wood usually dries out fast. If adequate foundation vent area is present (2 square feet per 150 linear feet of outside foundation plus 1/3 of 1 percent of the ground floor area), infected substructures dry out rapidly. Nevertheless, when walls and floors are opened to determine the extent of damage or to replace wood, leaving them open for a few days will hasten drying. Tight floor coverings like linoleum may impede drying of decayed wood under them, and probably should be lifted until drying is complete.

Poria has been found alive in the soil under buildings several years after decay had been stopped. Tests have been started to determine the value of fungicides in killing the water-conducting fungi in soil. If effective, soil fungicides might sometimes reduce the cost of control and be an added safeguard against recurrence.

Often it is simple for the expert to stop a *Poria* attack. Almost each case, however, is different, and all exigencies cannot be covered here. It is suggested that the home owner hire an expert repairman who will scrupulously follow the advice given here. In some cases encountered in this survey, all necessary corrections were not made during initial repairs. This almost always proved to be false economy, and led to a second or even a third major repair job. During the course of this survey no decay recurred in any case in which the owner followed the control recommendations completely.

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